

## I. Background on the Resource Conservation Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA), and its amendments, gives EPA the authority and obligation to ensure the safe handling of waste materials. RCRA does this in large part by requiring the Agency to develop regulatory standards covering the following topics:

The definition of a waste (or, under RCRA, a “solid waste”);

The definition of hazardous waste;

Safe handling requirements for hazardous waste (e.g., storage and transportation);

Treatment requirements for hazardous waste,; and

Safe disposal practices for both hazardous and non-hazardous wastes, including reuse.

For a discussion of the Toxicity Characteristic Leaching Procedure (TCLP), the most important of these topics are defining hazardous waste, and treatment requirements for hazardous waste. Wastes are classified as hazardous waste by one of two regulatory systems: listings or characteristics.

In developing hazardous waste listings, the Agency studies either the wastes generated by a particular industry (e.g., petroleum refining) or a common waste type (e.g., spent solvents), and determines whether the waste warrants listing as a hazardous waste. Many commercial chemical products are also listed, and would be hazardous wastes if they are unusable and become waste. Listed wastes are always hazardous, and are identified by reference to a narrative definition. No testing is required to determine whether or not a waste is listed; if the waste meets the narrative listing description, it is a listed hazardous waste<sup>1</sup>. The TCLP test has been used in many rulemakings to assess the potential of wastes to leach toxic constituents and contaminate groundwater, and determine whether listing is warranted. See 40 CFR 261.30-38.

The hazardous waste characteristics apply to all non-exempt<sup>2</sup> RCRA solid wastes. Any non-exempt RCRA solid waste exhibiting one of the four hazardous characteristics is classified as a hazardous waste. The hazardous characteristics are: ignitability, corrosivity, reactivity, and toxicity. The toxicity characteristic uses the TCLP test to consider the potential of wastes to leach hazardous constituents. Leached hazardous constituents could travel through the groundwater and subsequently contaminate drinking water wells. See 40 CFR 261.24

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<sup>1</sup> Generators of listed wastes that do not pose hazard to the environment, either as-generated or as a result of treatment, may petition to have their waste “delisted”. Delisting is done via rulemaking, in which the waste of the petitioner is assessed for potential hazards to the environment.

<sup>2</sup> There are a number of specific exclusions from regulation under RCRA. These include exemptions both from the definition of solid waste (e.g., piped domestic sewage) and from the definition of hazardous waste (e.g., household hazardous wastes, and a number of particular industrial wastes, including mining and mineral beneficiation wastes, oil exploration waste, and others).

Any waste designated as a hazardous waste is required to meet treatment standards before it can be placed (disposed or reused) on the land. These are commonly called the Land Disposal Restriction (LDR) regulations. The LDR treatment requirements are generally directed at either destruction (by incineration or chemical reaction) or immobilization (by stabilization/solidification) of the hazardous component(s) of the waste. Listed wastes are required to be disposed in “Subtitle C” hazardous waste landfills after treatment, while characteristic wastes can be disposed in non-hazardous landfills after they are decharacterized and meet other treatment requirements. For many wastes, a required treatment is not specified. Rather, a numerical standard is set, and TCLP is used to determine the effectiveness of treatment. See 40 CFR Part 268

A more comprehensive description of RCRA regulatory programs, presented in plain language, can be found in the RCRA Orientation Manual, which is available online at: <http://www.epa.gov/epaoswer/general/orientat/>

### What is TCLP?

The TCLP is a laboratory batch leaching test developed by EPA for use in its waste regulatory programs. TCLP was designed as a screening test to predict the potential release of both organic and inorganic waste constituents from land filled wastes into groundwater, a key pathway of concern for safe waste management.

TCLP simulates a “reasonable worst case” mismanagement scenario – co-disposal with municipal waste in a MSW landfill. Under RCRA, a waste is to be regulated as hazardous if it would pose undue hazard to human health or the environment were it to be mismanaged. Therefore, in deciding what waste is to be regulated as hazardous, the Agency asks the question “How would this waste plausibly be managed if it were not regulated as hazardous?”, followed by an assessment of the hazard posed under that management scenario. If the hazards posed are high, this plausible management is termed “mis-management”, and the waste is regulated as hazardous to prevent mismanagement. For general industrial waste, the Agency determined that codisposal in a municipal waste landfill represents plausible, worst-case mismanagement, and so TCLP incorporates key features affecting leaching in an MSW landfill. Key features of the TCLP test include:

- Leaching fluid of buffered acetic acid at pH 5 (pH 2.9 for highly alkaline waste)
- Liquid/Solid (L/S) ratio of 20:1, using 2 liters of leach fluid and 100 grams of waste
- Particle size of waste of 9.5 mm (achieved by grinding the waste prior to testing)
- The test strives to achieve equilibrium conditions (18 hours of tumbling)

As a screening test that is applied to circumstances where MSW codisposal is plausible, TCLP has been largely successful. However, if TCLP is used to predict leaching for situations that depart from the basic assumptions, the test results may not be accurate.

The 1999 SAB commentary also includes a description and discussion of the TCLP test.

TCLP is identified as Method 1311 in EPA/OSW's guidance manual for testing of waste, SW-846. The analytic method guidance is available online at: <http://www.epa.gov/epaoswer/hazwaste/test/main.htm>

### How is TCLP Used?

TCLP is used primarily in implementation of RCRA hazardous waste regulatory programs, but is used in other programs as well.

### RCRA Programs

#### Hazardous Waste Identification/Classification:

Toxicity Characteristic Regulation: This regulation is the original intended use of TCLP. Any non-exempt RCRA solid waste leaching too high a concentration of any of 39 chemicals (using TCLP), is a RCRA hazardous waste. The TC regulation concentrations are based on drinking water health standards, and a dilution/attenuation factor of 100. Although waste generators are not required to test, TCLP is part of the regulation, and TCLP results would authoritatively resolve any questions about whether a waste is a TC hazardous waste.

Listings: TCLP has been used in waste assessment to determine whether wastes are likely to leach hazardous chemicals at levels that may contaminate drinking water wells. Use of TCLP is not required, and other tests have been used in some instances.

Delistings: TCLP has been used to identify listed wastes which, either naturally or through treatment, do not pose the hazard for which they were listed, or other hazards, and may be safely managed as non-hazardous waste. TCLP is used as a matter of policy (EPA does not want to delist wastes that fail the TC regulation), but other leaching tests are also used in evaluating candidates for delisting.

#### Waste Treatment:

Land Disposal Restriction Treatment Requirements: TCLP has been used to measure the adequacy of waste treatment methods, and establish and implement treatment regulatory requirements. TCLP data form the basis for a number of the LDR treatment standards, and TCLP use is required to determine regulatory compliance with these standards.

Corrective Action: Remediation of active industrial sites is called Corrective Action. Modified treatment requirements for contaminated soils have been developed. Some of these modified requirements rely on TCLP and some, such as disposal in Corrective Action Management Units (CAMUs) allow flexibility in evaluating treatment effectiveness.

Risk assessment: TCLP data has been used to drive groundwater risk assessments for a number of wastes, but is not required, and other leach tests have been used also.

### Superfund Program

TCLP is the primary test that has been used in the past to evaluate the effectiveness of

stabilization/solidification treatment of metals-contaminated media, including in situ treated waste and ex situ treated waste later disposed on-site (EPA 2000).

TCLP use is required only if contaminated media becomes a hazardous waste, and the RCRA LDR treatment requirements are triggered. In situ treatment does not trigger the LDR regulation, and most ex situ treatment that includes on site final disposal does not either, so TCLP use is not required for evaluation of treatment effectiveness for these materials.

## State Programs

Industrial D Guidance: EPA's Industrial D Guidance cites TCLP (and other available leaching tests) as acceptable approaches to generating waste characterization input data for groundwater risk models. TCLP use is not required.

State Beneficial Use Programs: Some states rely on TCLP to evaluate the potential environmental impacts of reusing non-hazardous waste material, through requiring Beneficial Use permits. TCLP use is not required.

## Department of Energy Site Remediation

DOE has 44 sites needing clean-up under RCRA/CERCLA and other authorities. DOE has a goal of remediating 90% of these sites by 2006, at an estimated total cost of \$151B (DOE 2000). It is unclear TCLP may be required for some assessment, but not in all cases. EPA has not fully evaluated TCLP applicability to these sites.

## II. Past Science Advisory Board Comments

In 1991 and 1999, the SAB commented on the Agency's approach to the use of laboratory leach tests for assessing the leaching potential of waste and contaminated media (Add Cites). Both times, the SAB urged the Agency to conduct research to improve its understanding of waste leaching and the environmental factors that affect it and then incorporate that understanding into improved predictive tests. SAB noted that field validation of new tests would be critical before widespread use of the tests. Also, either a suite of tests or a flexible testing framework would be needed to make leach testing more reliable and accurate over the broad range of waste types and waste management conditions that are known to occur.

In the 1999 commentary, the SAB expressed concern about over-broad use of the TCLP. The commentary noted the outcomes of two legal challenges to particular uses of TCLP as illustrating problems with such over broad use of the test, and supporting the need for greater flexibility in testing. The commentary went on to assert that current science supports the development of more accurate tests that are reasonably related to the conditions controlling leachability under actual waste disposal conditions.

The 1999 commentary also cited a number of particular topic areas in which TCLP may perform sub-optimally: leaching kinetics and achievement of equilibrium in leach testing; reliance on a single set of test conditions (e.g., pH and liquid/solid ratio); the effects of colloids

on test results, particle size reduction of monolithic wastes; loss of volatile; and effects of aging and interactions with other wastes. The commentary also urged field validation of any new or revised tests before broad application in the field.

### III. EPA Projects/Activities Directed at Addressing SAB Concerns

#### A. Background

As a result of some of the program problems identified in the SAB 1999 commentary letter, and the more specific comments on TCLP, the Office of Solid Waste has been reviewing the test and its use in implementing EPA programs. While the Agency believes that TCLP remains a valid and useful screening test when used as originally intended, there are also many circumstances in which TCLP is not required by regulation, and in which codisposal with municipal solid waste is not plausible. When this is the case, use of alternatives that improve on TCLP's performance in the particular circumstances may be warranted, and is scientifically defensible.

OSW's policy perspective in improving leach testing is, first, that better science will result in better, more defensible, environmental decisions. By more reliably assessing the leaching potential of waste, the Agency can make environmental decisions that are more protective of human health and the environment, and are more cost-effective. OSW believes that developing a generalized leach testing approach, applicable over a broad range of waste types and management scenarios, is most likely to provide a consistent and coherent tool for environmental decision making.

A number of factors affect the leaching of constituents from waste, and the values and relative importance of these parameters will vary for different wastes and different disposal conditions. For studying the leaching of metals from waste, the pH of the disposal environment is usually a significant determinant of leaching, since the solubility of most metals of concern (Pb, Cd, As, etc) varies with pH. Solubility also varies with different salts of the metals, so redox conditions and other ions present are also important. The rate of leaching is also partly controlled by the amount of water passing through (or around) the waste, so the physical form and permeability of the waste is important, as is the liquid/solid ratio of a leach test. One of the difficult issues in developing leaching tests is deciding which of the parameters affecting leaching to vary (i.e., test at multiple values), and the range of values over which to test. It would be ideal to test at several values of each parameter known to affect leaching. Unfortunately, this would produce a testing matrix including dozens of individual tests, and would be prohibitively expensive. Therefore, priorities must be established for testing.

Either the disposal conditions or the waste properties can be the primary focus in accounting for this variability when developing an approach to leach testing. When variability in disposal conditions is the primary orientation in testing, tests would incorporate a plausible range of values for key parameters affecting constituent leaching (e.g., landfill pH, liquid/solid ratio, redox potential, etc). When variability in waste is the primary focus of test design, preliminary data about a waste would be generated (e.g., constituents of concern, physical form of the waste, etc.) and used to select a specific leach test tailored to the waste properties.

Neither approach is more correct than the other, although each lends itself better to different uses. Focus on the variability in disposal conditions better supports broad application

of testing in regulatory programs, because the range of plausible disposal conditions can be known (while the range of waste types is more difficult to know beforehand) and is largely independent of wastes generated that may be disposed there. This approach seeks a method to test how any waste would leach over the range of known landfill conditions. Further, focusing on disposal condition variability would not require much preliminary study of the waste, and the same testing regime could be broadly applied because it is independent of waste characteristics. The weakness of this approach would be in the possibility of failing to test over an adequate range of values for an environmental parameter of overriding significance for a particular, atypical, waste.

On the other hand, focusing on the variability of the waste properties lends itself to a more specific understanding of the leaching of a particular waste over some range of management conditions. It allows focus on the particular variables that are most important for the waste. However, it is not clear how this approach would be adapted to address multiple constituents of concern. Multiple tests or tests tailored to the combination of constituents of concern in a particular waste might need to be developed, resulting in a variety of tests tailored to waste constituents, but difficult to relate to one another or other wastes.

As a practical matter, OSW's approach must also try to address the technical problems with TCLP identified by the SAB. Agency focus to date has been on metal-bearing waste. This is because program issues with leach testing have mostly involved metal-bearing wastes, and because of resource limitations. Therefore, an approach that considers TCLP's weaknesses in leaching of metals is appropriate. These include assessing leaching under final, equilibrium, test conditions; generating multiple data points for each waste (rather than a single data point), and giving some appropriate credit to waste form.

#### B. Specific OSW Projects and Program Activities

EPA's Office of Solid Waste (OSW) and Office of Research and Development (ORD) have engaged in a number of activities since the latest comments from the SAB. These are discussed briefly below.

##### Review of EPA programs for flexibility in use of leach tests:

The discussion above identified required uses of TCLP and some instances in which TCLP is not required. A more complete discussion of situations in which leach testing is useful, but TCLP is not required or has not been used, appears below.

**RCRA Corrective Action (CA) Program:** RCRA Corrective Action site remediations involving in-place treatment of soil, or on-site disposal of treated soil (within an "area of contamination" or AOC) do not trigger LDR requirements. Also, new Corrective Action Management Unit (CAMU) rules (effective April 2002) allow Regional Administrators (RAs) to use alternative leaching tests in determining CAMU waste treatment effectiveness, if disposal conditions are known, and the RA finds that an alternative test would better represent conditions that affect leaching at the site than does TCLP.

**Superfund Remediations:** CERCLA site remediations involving in-place treatment of soil, or on-site disposal of treated soil (in "contiguous areas"; which is analogous to the Corrective Action AOC policy) do not trigger LDR requirements. Therefore, treatment

effectiveness may be measured using tests other than TCLP. Also, the Corrective Action CAMU rules may be considered an applicable or relevant and appropriate requirement (ARAR) for CERCLA site remediations, and eligible sites can take advantage of the flexibility in the CAMU treatment requirements, including use of non-TCLP tests for assessing treatment effectiveness.

**RCRA Listing/Delisting Determinations:** While historically used in making listing and delisting determinations, TCLP is not required (or is not solely required). Recent listing determinations for inorganic chemicals and chlorinated aliphatics manufacturing relied on tests other than TCLP when EPA knew that waste was not going to MSW management. In delistings, EPA policy is that no waste failing TC/TCLP can be delisted. EPA Region 6 also requires leach testing at 3 different pH values (using the TCLP framework) in support of delisting petitions.

**RCRA LDRs:** The LDR treatment requirements for mercury in chlorinated aliphatics manufacturing wastes was based on leach testing data done at the pH of the expected disposal conditions, a pH of approximately 10.

**State Regulatory Programs:** A number of state programs rely on leach testing to assess the potential hazards of non-hazardous waste being reused, disposed, or remediated. State beneficial reuse permitting programs currently rely on TCLP, totals or other tests, even though reuse conditions are rarely similar to MSW landfill conditions. Testing that better reflects reuse conditions may broaden waste reuse opportunities. States also manage non-hazardous industrial wastes. EPA has proposed and will soon finalize guidance to states in making risk-based management decisions for industrial non-hazardous waste. Leach testing is one aspect of hazard assessment in this guidance, and alternatives to TCLP that reflect actual disposal conditions will be useful in implementing this guidance. Finally, as states take on more remediation responsibility as part of Brownfields implementation, the availability of accurate evaluative tests for site assessment and treatment of metal-bearing wastes will become more critical.

#### Landfill Leachate Data Collection

In order to better understand leachate generated by landfills, EPA collected secondary data on the properties of landfill leachate in 2000<sup>3</sup>. The database includes data from hazardous and non-hazardous landfills, including construction and demolition (C&D) landfills, industrial non-hazardous landfills, MSWLF, and several industry “captive” landfills (i.e., landfills owned and operated by industrial facilities, and likely receiving more than one waste, but only waste from that facility). Data on pH, chemical constituent concentration, and other parameters of interest were collected (EPA 2000). EPA is currently updating the database.

#### Mercury Waste Treatment Alternatives

EPA recently co-funded (with DOE) a study of alternative treatment methods for high-mercury (more than 260 mg/kg) wastes. Currently required treatment is retort/recovery for reuse, or amalgamation. However, DOE was concerned that these treatments may not always be cost-effective, particularly for mixed radiologic/chemically hazardous waste. Both TCLP and

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<sup>3</sup> Only data available in electronic format were included in the database, due to resource limitation. Therefore, the data may not be broadly representative of landfill leachate quality.

alternatives that examine waste constituent leaching over a range of pH and L/S ratios were used to evaluate Hg waste treatment effectiveness in reducing leaching. The testing showed that in some instances, reliance on TCLP alone would have led to poor decisions about what treatments would be appropriate (see Sanchez et.al, 2002).

#### Leach Testing Guidance

OSW is currently developing a document intended to compile and present current knowledge about waste leaching and leach testing. It would also seek to provide guidance to federal and state regulators, and other interested parties, about how to most appropriately test waste for leaching potential under a range of circumstances. A complete draft is not expected to be completed until January 2004.

#### C. ORD Projects/Activities

Scientists at the National Risk Management Research Laboratory (NRMRL), in Cincinnati, OH, have developed a research plan for ongoing EPA research on waste leaching. NRMRL Cincinnati has also recently begun additional study of arsenic leaching and treatability of arsenic-bearing wastes. This work will rely in part on multi-pH and multi-L/S leach testing methods (EPA 2003).

EPA's ORD/NRMRL laboratory in RTP, NC, is currently using multi-pH and multi-L/S ratio leach testing to examine Hg leaching from coal combustion residues. Air pollution control regulations to reduce mercury emissions from coal fired power plants are currently under development. Once implemented, the regulations will result in higher mercury levels in coal ash, air pollution control residues, and other wastes. Leach testing of wastes from emissions control pilot plants will support an assessment of the net environmental benefit of the mercury air emissions controls.

#### D. University Research

Researchers at Vanderbilt University have been particularly active over the past 10 years in waste leaching research and leach test method development, focusing primarily on leaching of metals. A number of publications over that time culminated in publication of a proposed overall framework for leach testing of metal-bearing wastes (Kosson, et.al, 2002). The framework is based on examination of equilibrium solubility of waste constituents over a range of pH values and a range of L/S ratio values. The framework also examines the diffusion-limited leaching of constituents from monolithic or compacted granular waste materials. Leaching data generated is then used to estimate the rate of constituent leaching over various time frames. The Vanderbilt group has also published several papers examining the effects of intermittent wetting (as in rainfall events) on waste leaching, and reaction of waste exposed to the open air to form carbonates, and resultant declining pH of the wastes.

EPA believes the framework proposed by Dr. Kosson and his collaborators represents a significant advance in leach testing. The approach is based on assessment of fundamental factors affecting metals leaching, considers a range of values for these key parameters, and is designed to generate data to facilitate environmental decision making. A key aspect of EPA's request for SAB input concerns how to consider this work, and how best to proceed in developing it for more routine use.

#### IV. Key Issues Not Yet Addressed

The two SAB letters addressing leach testing outline a comprehensive program for developing and applying a better understanding of waste leaching. The SAB's advice includes conducting substantial research into how waste leaches and what factors affect leaching, development of tests that incorporate this understanding, and field validation of tests before widespread use in waste management programs. Agency resource constraints have dictated a modest pace for this work, and a number of areas remain to be addressed. These include: study of the relationship between laboratory tests, fate and transport models, and leaching in the field; more detailed study of the effect of redox conditions on leaching and transport; more study of the effects of colloid formation in laboratory leach testing; and aging effects and impacts of microbial activity on long-term leaching.

#### V. Conclusions To-Date Based on Program Review and Leach Testing Work

While many questions and much research remain, the Agency seeks an opportunity for a free and vigorous exchange of ideas with a knowledgeable committee of the SAB, and the public, before it embarks on further work. The Agency does not look for consensus recommendations at this time. Instead it seeks a variety of perspectives to enrich its understanding of two issues. The first is Agency consideration of current research, and the potential to apply it to improve particular programs, specifically programs that do not now require the use of the TCLP. The second is the direction for long-term research work to further develop fundamental understanding of leaching that would improve the predictive capability of test suites or testing frameworks.

The Agency would welcome SAB reaction to its preliminary conclusions, which are:

1. Laboratory testing conditions should, to the degree possible (and practical), anticipate the plausible range of field conditions affecting waste leaching in disposal and reuse situations. These conditions will be most realistically represented by a distribution of values for factors affecting leaching, and testing should reflect this range of values to the degree possible.
2. Conditions (e.g., pH) present at the end of a test (rather than initial test conditions) should be the basis for comparison with field conditions.
3. For assessing metals leaching, pH is the strongest predictor of leaching potential in most cases. Other important factors include infiltration rate/liquid to solid ratio, the oxidation/reduction environment, effect of common ions and ionic strength, effects of external factors (codisposed waste, biological activity, etc), and exposure to ambient air. The relative importance of these factors is likely to vary for different wastes.
4. The above conclusions strongly support the development of multiple leaching tests, or a flexible testing framework. Selection of suitable leaching test should be made based on a number of factors: anticipated use of test results (generic or site-specific), waste characterization, the range of plausible disposal or reuse conditions, and previously available information on the subject waste or similar wastes. Such information should include past leaching studies, chemical analysis, acid neutralization capacity, waste form and structural integrity/strength, and other relevant data.

5. Modeling may also play an important role in relating laboratory and field conditions to one another, and in using leach test results to assess the leaching potential of waste.

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